

Factors Leading to and Treatment of Aneurysmal Perforation during Coil Embolization

Analysis of 105 Consecutive Cases

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Summary

It is important to know the characteristics of aneurysms that tend to cause perforation and treatment of these perforations to reduce the morbi/mortality of the endovascular treatment for intracranial aneurysms. Factors leading to aneurysmal perforation were analyzed from the view points of aneurysmal status (ruptured or unruptured), size and direction of aneurysmal dome from the parent artery and treatment of perforation during GDC embolization was discussed in 105 consecutive cases. Perforation occurred in three small aneurysms (less than 3 mm in diameter or depth) where the direction of the dome is the same as that of microcatheter advancement. Perforation occurred when a microcatheter was advanced to counteract catheter recoil caused by coil deployment. Haemorrhage occurred in all cases immediately following microcatheter and coil perforation into the subarachnoid space. In all cases, bleeding was controlled by deploying the coil so that it extended from the subarachnoid space back into the intraaneurysmal cavity. In two cases, surgical clipping was required to treat the incompletely obliterated aneurysm. No additional permanent neurological deficit occurred as a result of any of the three perforations. Special care should be taken during the embolization of small

aneurysms (less than 3 mm in minimal diameter) where, owing to the shape of the lesion, or fixation of a microcatheter by the stent strut, the antegrade force of the cannulating microcatheter is transmitted directly toward the aneurysm dome.

Introduction

Since the report of initial clinical results¹, endovascular treatment of intracranial aneurysms using electrolytically detachable platinum coils has evolved as an accepted alternative to surgical clipping. The endovascular approach has gained considerable attention in the treatment of aneurysms of the posterior circulation, of multiple aneurysms, and those in patients with high surgical risk^{2,3}. However, there still exists the potentially fatal risk of perforation of an aneurysm during embolization^{2,4-18}. From January 1998 to December 2001, we treated 105 consecutive cases of cerebral aneurysms using Guglielmi detachable coils (GDC coils, Target Therapeutics, Fremont, CA). In these 105 cases, three intraprocedural aneurysm perforations occurred. We analyzed these cases to discover common factors related to these perforations. We present these cases and the methods used to treat this complication.

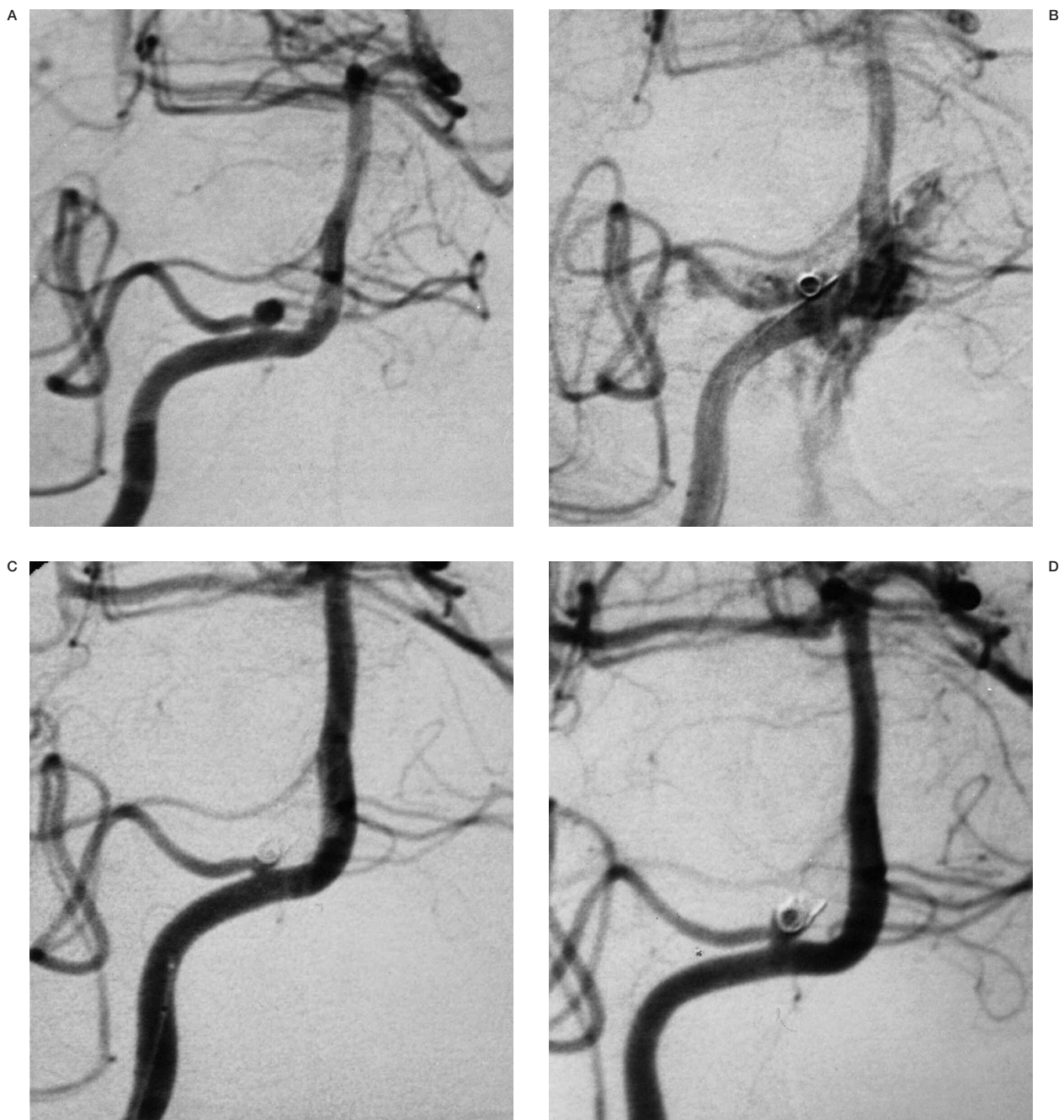


Figure 1 Right vertebral angiography (Antero-posterior view). A) A small aneurysm at the junction of the vertebral artery and posterior inferior cerebellar artery was demonstrated before embolization. B) Extravasation from the aneurysm was noticed. A part of the introduced coil was extruded into the subarachnoid space. C) Extravasation was not demonstrated and the aneurysmal lumen was not opacified. D) The inner part of the embolized aneurysm was opacified with a partial extrusion of the coil.

Material and Methods

Between January 1998 and December 2001, 105 consecutive intracranial aneurysms (103 patients) were treated in our institute using en-

dovascular deployment of GDC coils. Ruptured aneurysms were 57 (57 patients) and unruptured ones were 48 (46 patients). Male/female ratio was 39/64. Their ages varied from 31 to 91 years (60.9 years in average). Thirty-six

treated aneurysms were located in the internal carotid artery, six in the anterior communicating artery, five in the middle cerebral artery, three in the posterior cerebral artery, 23 in the basilar tip, four in the basilar-superior cerebellar artery, six in the basilar trunk, and 22 in the vertebral artery. Treatment was performed under general anesthesia and with full systemic heparinization as a rule. The size of an aneurysm was measured by calibration to externally-placed radiopaque markers. In all cases, a microcatheter was navigated into the aneurysm under road mapping mode and an appropriate number of GDC coils were introduced into the aneurysm under constant fluoroscopic guidance. We encountered three cases of intraprocedural aneurysm dome perforation by the microcatheter during coil deployment. These cases were presented and the characteristics of perforated aneurysms were analyzed from the following points.

1) *The status of the treated aneurysms.* Does aneurysmal perforation tend to occur in ruptured aneurysms?

2) *The size of the aneurysm.* Does aneurysmal perforation tend to occur in the smaller aneurysms whose minimum diameter is less than 3 mm?

3) *The direction of aneurysmal dome from the parent artery.* The angle between the longitudinal direction of the aneurysmal dome and the parent artery was measured on the angiogram in which the aneurysm was clearly separated from the parent artery. If this angle was smaller, the push-force of the coil or microcatheter was thought to be transmitted directly toward the aneurysmal dome. It was examined whether aneurysmal perforation tended to occur in aneurysms with a smaller angle ($\leq 45^\circ$) in ten aneurysms less than 3 mm in minimum diameter. Fisher's exact probability test was used for statistical analysis.

Results

1) *The status of aneurysms.* Fifty-seven aneurysms were ruptured and forty-eight unruptured. Two perforated aneurysms were ruptured and one was unruptured. There was no statistical significance between aneurysmal perforation and status of aneurysm (ruptured or unruptured).

2) *The size of aneurysms.* Ten were aneu-



Figure 2 CT findings after embolization. Subarachnoid haemorrhage and intraventricular high density areas were demonstrated with hydrocephalus.

rysms less than 3 mm in minimum diameter and 95 were larger than 3 mm. Three of ten aneurysms less than 3 mm in minimum diameter were perforated during embolization but none of the 95 aneurysms larger than 3 mm were perforated. Aneurysms less than 3 mm in minimum diameter significantly tended to cause perforation during coil embolization ($P < 0.01$, Fisher's exact probability analysis).

3) *The direction of the aneurysmal dome from the parent artery.* Six aneurysms had small angles of less than 45° while four had larger angles. Two perforated aneurysms had an angle less than 45° but one had 90° . However, this case (case 3) with an angle of 90° was treated with stenting and coil embolization. The microcatheter was fixed between the stent strut and the wall of the middle cerebral artery. Therefore, push-force was directly transmitted toward the dome of the aneurysm and resulted in perforation in spite of the large angle in this case. Although there existed no statistical significance between the angle and aneurysmal perforation, all perforated cases had the situa-

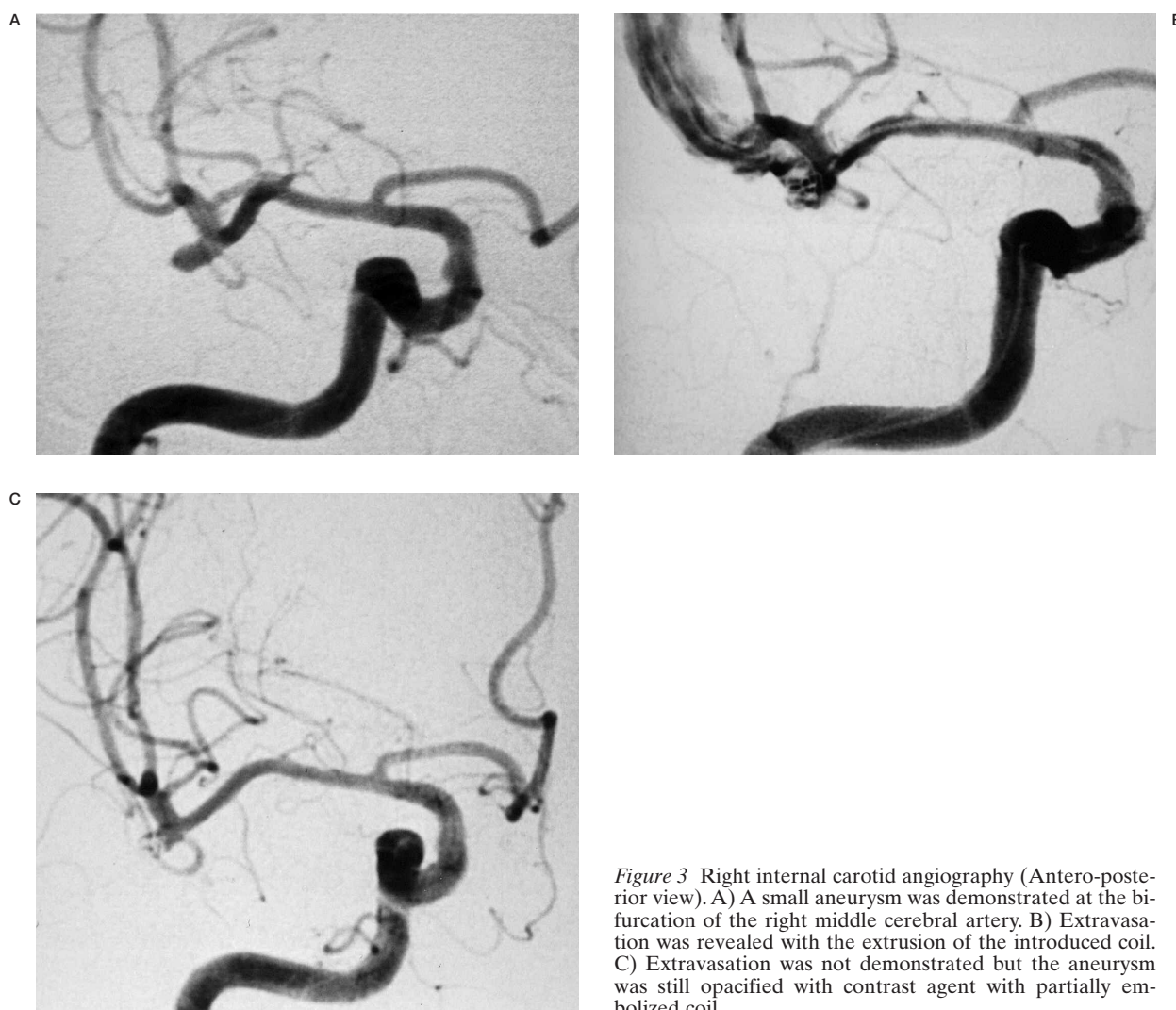


Figure 3 Right internal carotid angiography (Antero-posterior view). A) A small aneurysm was demonstrated at the bifurcation of the right middle cerebral artery. B) Extravasation was revealed with the extrusion of the introduced coil. C) Extravasation was not demonstrated but the aneurysm was still opacified with contrast agent with partially embolized coil.

tion that the push-force of the coil or microcatheter was directly transmitted toward the aneurysmal dome.

Case Presentation

Case 1: A 44-year-old woman with sudden onset of severe headache was emergently transferred to our hospital as a Hunt and Kosnick grade II with CT findings of subarachnoid haemorrhage mainly within the posterior fossa. Angiography demonstrated a small aneurysm (2 x 2 x 3 mm) at the posterior inferior cerebellar artery origin (figure 1A). The option of endovascular treatment was initially chosen because of the aneurysm's location, despite its small size. A Prowler-10 microcatheter (Cordis

Endovascular, Miami Lakes, Florida) was navigated into the aneurysm, and a GDC-10 soft coil (2 mm x 8 cm) was gently introduced. Near the end of the insertion of this first coil, the microcatheter had recoiled out of the aneurysm cavity and into the lumen of the parent vertebral artery. Gentle antegrade force was then applied to the microcatheter which caused the microcatheter and coil to perforate the aneurysmal dome. Angiography was immediately performed and demonstrated extravasation of contrast medium into the subarachnoid space (figure 1B). Heparinization was immediately reversed with protamine sulfate and the patient's elevated blood pressure was brought under control. The coil extruded into the subarachnoid space was left and the microcatheter

was gently pulled back into the aneurysmal lumen and the remaining coil placed in the aneurysm lumen. Repeat angiography several minutes later showed neither contrast extravasation nor residual aneurysm lumen (figure 1C). An attempt was made to navigate the microcatheter (that had once again recoiled into the vertebral artery) back into the aneurysm to place an additional coil. However, this was unsuccessful due to the presence of the initial coil. Following the conclusion of the procedure and recovery from general anesthesia, the patient was somnolent but without new focal neurological deficit. A brain CT study demonstrated acute hydrocephalus, prompting ventriculostomy placement (figure 2). The patient underwent follow up angiography two and four weeks after embolization that demonstrated aneurysmal recanalization (figure 1D). The patient was then treated with surgical clipping by drilling the jugular tubercle via a retrosigmoid approach. Following surgery, she was discharged home without neurological deficit.

Case 2: A 69-year-old woman with a chronic cerebellar infarction was referred to our hospital for treatment of bilateral unruptured middle cerebral artery aneurysms (figure 3A). The patient opted for endovascular therapy of her bilateral aneurysms in a single session to avoid bilateral craniotomies associated with surgical clipping. Under general anesthesia and systemic heparinization, a microcatheter (Prowler-14, Cordis Endovascular) was navigated into the right MCA aneurysm with dimensions of 2 x 2 x 3 mm. A GDC coil (3 mm x 6 cm soft SR) was introduced into the lumen of the aneurysm. The microcatheter recoiled into the parent MCA during the deployment of this coil. While the microcatheter was gently pushed back into the aneurysmal lumen, aneurysm dome perforation occurred (figure 4). Angiography demonstrated extravasation of the contrast agent (figure 3B). Heparin was immediately reversed by intravenous protamine sulfate. The extruded coil was left in the subarachnoid space and the remaining coil was placed in the aneurysm lumen. Angiography several minutes after the perforation demonstrated cessation of extravasation. However, there was residual opacification of the aneurysm (figure 3C). Additional coil embolization was attempted using a smaller coil (2 mm x 2 cm soft), but this was unsuccessful due to persistent catheter recoil

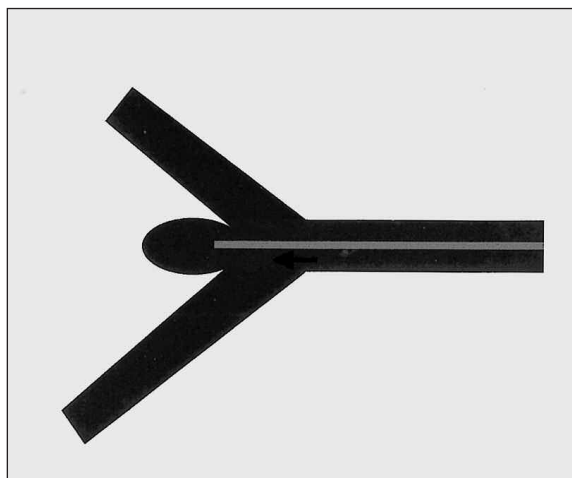


Figure 4 Schema of case 2: the advancing force of a catheter was directly transmitted to the direction of the aneurysmal dome.

during coil placement. Thus, the endovascular approach was abandoned. Post-procedure CT scanning demonstrated subarachnoid blood and contrast as well as acute hydrocephalus. The patient immediately underwent surgical aneurysm clipping and ventriculostomy placement. By the first post-operative day, the patient's mental status was intact without focal neurological deficit. Several days later, transient disorientation due to vasospasm occurred, but with appropriate medical management it resolved completely without new neurological deficit. Her left middle cerebral aneurysm has been followed up without any treatment.

Case 3: A 91-year-old woman was admitted following the sudden onset of severe headache. CT findings demonstrated massive subarachnoid haemorrhage. Her status was judged to be grade IV (Hunt and Kosnik). Angiography demonstrated a wide-necked aneurysm (4 x 3 x 3 mm) of the left middle cerebral arterial trunk (figure 5A). Endovascular therapy for her lesion, chosen due to her age and neurological status, was performed under general anesthesia three weeks after the occurrence of subarachnoid haemorrhage. A 6 F delivery catheter was introduced into the left common carotid artery and an AVE GFX 3 mm x 12 mm coronary artery stent (Medtronic, Minneapolis, MN) was delivered into the middle cerebral artery and deployed at six atmospheres of pressure across the aneurysm neck over a Transend-EX 0.014" microguidewire (Boston Scientific,

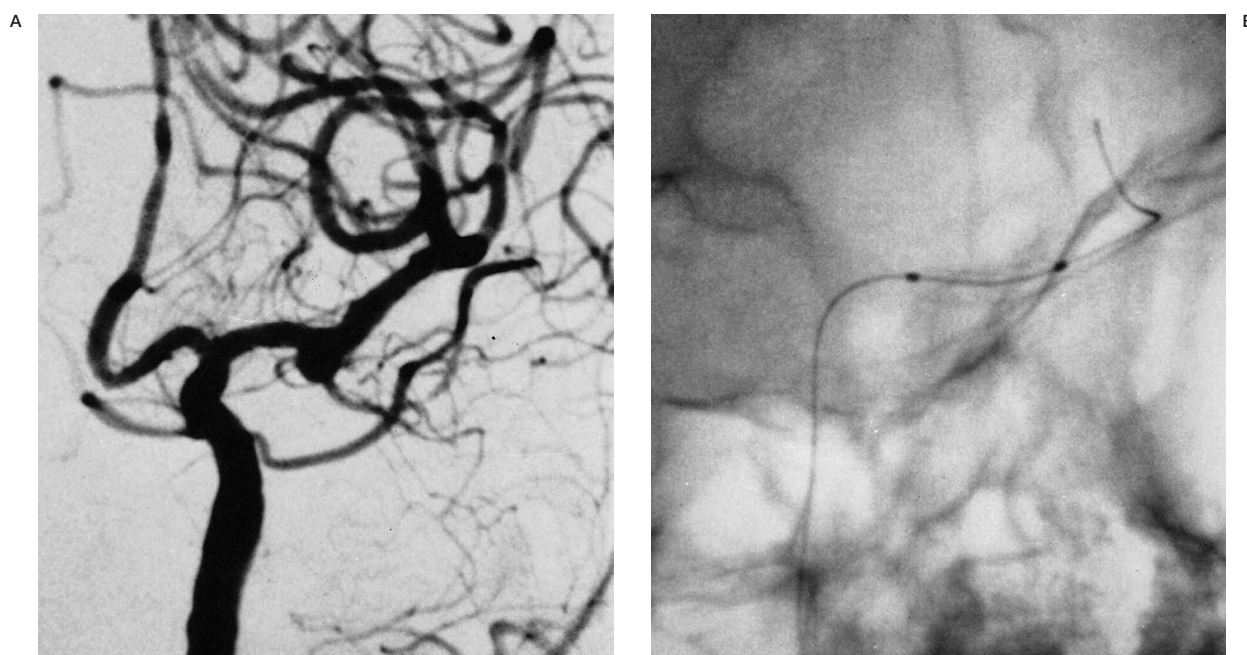
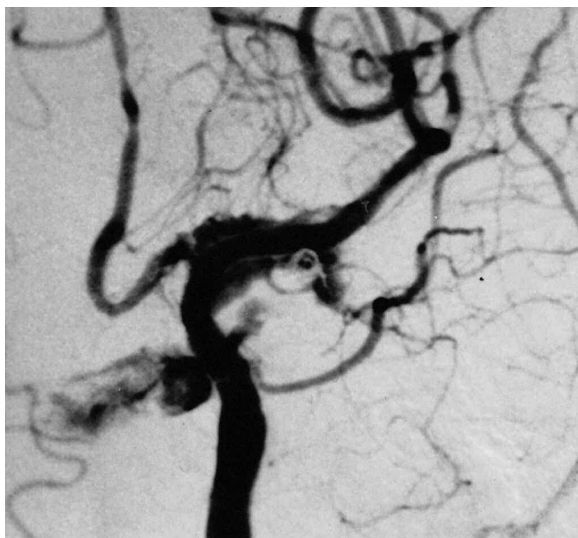


Figure 5 Left internal carotid angiography (antero-posterior view). A) A wide-necked aneurysm was demonstrated in the left middle cerebral arterial trunk. B) A stent was deployed to cross the neck of the aneurysm. C) Extravasation was demonstrated due to the perforation of the aneurysm by the second coil. D) Extravasation was revealed again when a microcatheter was retrieved. E) Extravasation was not noticed with complete disappearance of the aneurysm. A part of the second and third coils were extruded into the subarachnoid space.

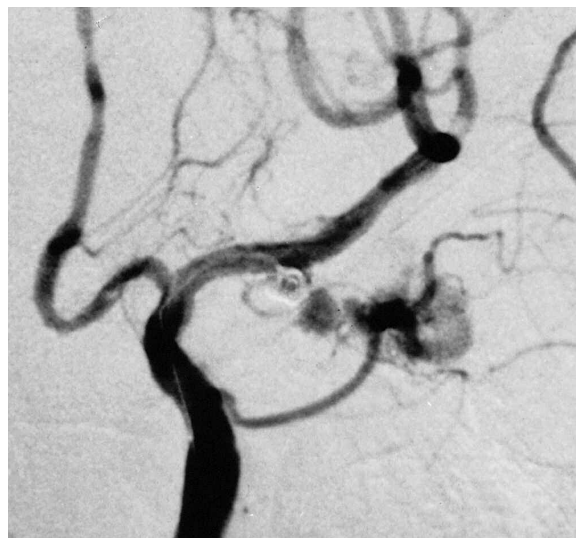
Table 1 Summary of ruptured aneurysm cases during coil embolization

Authors & Year	No. of treated ANs	No. of perforations	No. of death	Size
Byrne, et Al, 1995	83	3	1	unknown
Houdart, 1996	315	4	0	unknown
Malisch, et Al, 1997	104	4	2	unknown
Raymond, et Al, 1997	75	6	3	5/6 < 5 mm
Viñuela, et Al, 1997	403	11	5	9/ 11 < 10 mm
Cognard, et Al, 1998	236	6	2	unknown
Debrun, et Al, 1998	152	4	2	unknown
Kuether, et Al, 1998	77	2	2	unknown
Leber, et Al, 1998	134	2	2	unknown
McDougall, et Al, 1998	200	4	1	7, 7, 10 mm and giant
Ricolfi, et Al, 1998	91	4	1	3, 3, 3, 4 mm
Murayama, et Al, 1999	120	1	0	unknown
Solander, et Al, 1999	79	1	0	unknown
Vanninen, et Al, 1999	52	3	0	3, 3, 12 mm
Sluzewski, et Al, 2001	264	7	2	2 - 12 mm
Terada, et Al, 2001	105	3	0	2, 2, 3 mm
<i>total</i>	2490	65(2.61%)	23(0.92%)	

C

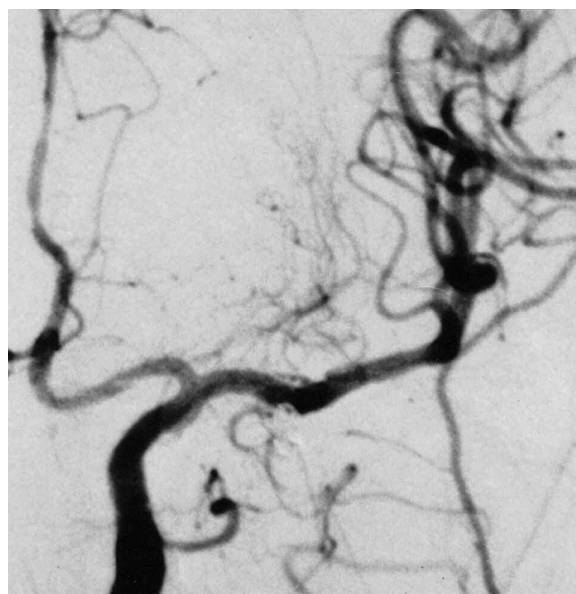


D



Boston, MA) (figures 5B,C). After stent deployment, a steam-shaped (J shape) tracker-10 microcatheter was introduced through the stent struts and into the aneurysm (figure 6). A soft GDC SR coil (2 mm x 8 cm) was introduced into the aneurysm and detached. We attempted placement of a second soft GDC SR coil (2 mm x 4 cm) which caused microcatheter recoil into the parent vessel near the completion of coil delivery. While trying to counteract this with gentle antegrade force applied to the microcatheter, the aneurysm dome was perforated. Angiography demonstrated contrast extravasation into the subarachnoid space (figure 5D). Heparinization was immediately reversed with protamine sulfate. The second coil was deployed both within the subarachnoid and intraaneurysmal spaces and then electrolytically detached. Post-coil deployment angiography initially revealed no contrast extravasation. However, when the microcatheter was withdrawn, repeat carotid angiography once again demonstrated subarachnoid contrast extravasation (figure 5E). The microcatheter was immediately reintroduced into the aneurysm lumen and another soft GDC SR coil (2 mm x 4 cm) was deployed. It partially entered the subarachnoid space with the remainder of the device coiling within the aneurysm lumen. At that time, angiography demonstrated complete obliteration of the aneurysm without contrast extravasation. The coil was detached and the microcatheter was withdrawn. Angiography demonstrated complete disappearance of the

E



aneurysm (figure 4F). A CT scan showed acute hydrocephalus, requiring ventricular drainage. Initially, post-procedure, her level of consciousness was somewhat depressed, but there were no new focal neurological findings. Oral ticlopidine (200 mg BID) was administered to prevent stent thrombosis and stenosis. Three weeks after embolization, the patient underwent ventriculo-peritoneal shunt placement. Although her level of consciousness had improved, she remained somewhat disoriented. Her motor and sensory examinations were intact.

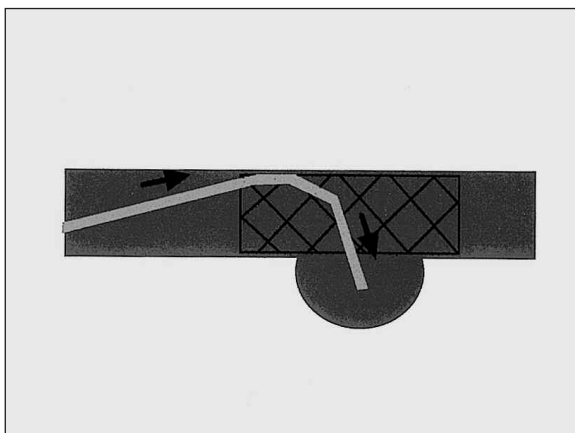


Figure 6 Schema of case 3: the movement of the microcatheter was restricted between arterial wall and stent struts. The advancing force of a microcatheter was directly transmitted to the direction of the dome as shown by arrows.

Discussion

The rate of rupture during coil embolization of cerebral aneurysms varies among studies^{1,2,5-18}. Viñuela²⁰ reported 11 cases of procedure-related rupture (six of these being fatal) out of 403 aneurysms treated following subarachnoid haemorrhage, for a rupture rate 2.7%. According to the summarized data of aneurysmal perforation during coil embolization, including ours, the overall rupture and mortality rates were 2.61% and 0.92%, respectively^{1,2,5-18} (table 1). The purpose of this paper is to focus on the mechanism of perforation and treatment of the resulting subarachnoid haemorrhage. Previous papers reported that smaller aneurysms (< 4 mm in diameter) and placement of the first embolization coil tend to be associated with procedure-related ruptures. Our cases had these characteristics. As regards these proposed mechanisms of the rupture in small aneurysms, smaller GDC coils, of the 2-3 mm diameter range, are thought to possess greater shape memory than larger coils. Therefore, the force applied against the aneurysm wall during coil introduction is possibly higher in smaller aneurysms than larger ones. Another cause of the perforation in our cases 1 and 2 was the direction of the growth of the aneurysms. In smaller aneurysms, if the microcatheter recoiled from the aneurysm lumen after detachment of the initial coil, it was very difficult to reintroduce the microcatheter into the aneurysm to effect complete embolization.

Therefore, it was desirable to keep the microcatheter within the aneurysm with gentle antegrade force. However, if the direction of the aneurysmal dome was different from the direction of catheter advancement the microcatheter migrated out of the aneurysm and excessive force was not directed at the aneurysm dome. In cases 1 and 2, the direction of the aneurysm's dome was the same as that of catheter advancement (figure 4). Therefore, when the microcatheter was pushed, the force was transmitted directly to the dome and caused perforation. In case 3, the direction of the aneurysm dome was different from the direction of catheter advancement, but in this case the microcatheter was fixed in the stent struts. Thus, the motion of the microcatheter was restricted and microcatheter and GDC coil antegrade force were directly transmitted to the aneurysm dome as in cases 1 and 2 (figure 6). This type of rupture is similar to the case of perforation during embolization using the balloon remodeling technique, which restricts the motion of the microcatheter as reported by Phatouros¹⁹.

The treatment of embolization-related perforation is to reverse systemic heparinization, reduce the blood pressure, leave the coil across the perforation point extending from the subarachnoid space back into the aneurysm lumen, and continue packing the aneurysm. General anesthesia is very helpful to continue the procedure without patient motion and to control the blood pressure. Willinsky et Al²⁰ reported a method to embolize the aneurysm from the newly introduced microcatheter, leaving the perforating microcatheter across the aneurysmal wall. This method is acceptable for larger aneurysms into which introduction of a second microcatheter is possible. However, this would prove difficult or impossible in smaller aneurysms, as in our cases. The most important point is not to withdraw a microcatheter or coil but to leave a coil across the rupture point when a perforation occurs. A microcatheter should be gently withdrawn even if hemostasis is confirmed on angiography after GDC detachment. In case of rupture, a microcatheter in the aneurysmal lumen may act as a plug for continued hemostasis, as shown in our case 3. In such cases, immediate replacement of a microcatheter and additional coil embolization should be attempted.

It is important to know that smaller aneurysms (< 3 mm) have a higher chance of causing embolization-related perforation. In addition, if the direction of catheter advancement is the same as the direction of the aneurysmal dome, excessive force applied to

the microcatheter or embolization coil in the aneurysm should be avoided.

More flexible coils with specialized shapes (e.g., diamond shape) or coils designed to accelerate fibrosis²¹ should be applied to this type of aneurysm.

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